Motorcycle Safety Foundation Mini-Module

Topic: Cornering — **General Time**: 20-30 minutes

Rationale: Many single vehicle motorcycle mishaps occur as a result of the rider over-riding his/her abilities and/or using improper cornering techniques. Most crashes are related to speed too fast for conditions or improper judgment. Over 40 percent of motorcycle fatalities are directly related to single vehicle crashes when negotiating a curve or turn. According to motorcycle research, in single vehicle crashes, motorcycle rider error was present as the crash precipitating factor in about two-thirds of the cases, with the typical error being a slide and fall due to over-braking or running wide on a curve due to excess speed or under-cornering. This mini-module addresses the knowledge, skills, attitudes and habits that may provide more effective rider behavior when riding a motorcycle through corners. (Note: In 2001, MSF introduced new phrases for the four steps in cornering. The older materials use "Slow, Look, Lean, Roll"; the newer materials use "Slow, Look, Press, Roll." The rider actions are the same, but the newer terminology more clearly explains rider actions.)

General Objective: Upon completion of this mini-module, riders will have an understanding of the risks related to cornering, a basic knowledge of fundamental cornering techniques, and an appreciation of using risk-reducing strategies to maintain safety margins when negotiating curves.

Specific Objectives

Upon completion of this mini-module, each rider will be able to:

1. Identify the risks associated with cornering.
2. State the percent of motorcycle crashes related to cornering.
3. Assess personal risk taking decisions related to strategies for safe and effective cornering.
4. State the four steps of proper cornering (slow, look, press, and roll) and provide a definition of each.
5. Explain the importance of visual perception and safety margins.
6. State the effects of personal capabilities and limitations as well as one's motorcycle capabilities and limitations.
7. Name several tire characteristics and surface conditions that may affect the ability to corner.
8. Tell how peer pressure may affect risk taking, particularly in choosing an appropriate speed for corners.
9. Determine personal strategies to minimize the risk factors related to cornering.
10. Name common errors when cornering and tell how to correct them.

Materials and Items Needed (Some or all could be used.)

Classroom setup with small group capability
Flipchart/Markers and/or Chalk Board/White Board
Training Aid "Riding with Control"
Supplements related to this module

1. Cornering Supplement #1: "Where Should Riders Look"
2. Cornering Supplement #2: "Traction"
3. Cornering Supplement #3: "Cornering"
4. Cornering Supplement #4: "Leaning In and Leaning Out"
5. Cornering Supplement #5: *Motorcycling Excellence* Chapter 14 "Cornering"
6. Cornering Supplement #6: *Motorcycling Excellence* Chapter 15 "Low-and-High Speed Turning"

Related Terms

Apex, Head Turn, Counter-steering, Path of Travel, Constant Radius, Decreasing Radius, Increasing Radius, SEE, Blind Curve, Crowned Road, Camber, Approach Speed, Entry Speed, Exit Speed, Centrifugal Force, Center of Gravity, Traction, Coefficient of Friction, Lean Angle, Lean In, Lean Out

Learning Activities:

Regardless of the activities used, first ask participants questions about their needs, interests and concerns in relation to the topic. Ask what they expect out of the activity. If no concerns are identified, initiate a discussion of rider experiences in cornering and negotiating curves. Note: This particular mini-module contains several supplements for use in achieving objectives. Within each activity is listed a series of questions to highlight important information. A facilitator should consider duplicating these questions for use as handouts/references during the small group interactions.

Learning Activity A

1. Show the training aid "Riding with Control." (Have riders focus on aspects related to cornering and see if it matches their experiences.) Questions to highlight important information about content include:
    a. What are the four forces to consider when managing traction?
    b. What are the four parts of turning?
    c. Where does a rider look when turning or cornering?
    d. What technique is used to lean through a curve?
    e. What is accomplished by a roll-on in a curve?
    f. What is accomplished by managing traction and maximizing the traction reserve?
2. Using small groups, have riders answer two questions: a. "What is the main cause of motorcycle crashes in cornering?" and b. "How can a rider reduce the risks related to cornering?"
3. Have a member of each group report key points brought up in the discussion.
4. Using small groups, discuss the potential effects of peer pressure when riding through corners.

Learning Activity B

1. Hand out copies of Cornering Supplement #1 "Where Should Riders Look?"
    - Note: This article was written for MSF certified RiderCoaches, but the information about effectively using the eyes applies to all motorcyclists. A key point is to have riders keep their eyes moving and look well ahead as they check for factors that could increase risk.
2. Using small groups, have each group read a few paragraphs (Include box in the middle of the second page).
3. Have each group report about the content and suggestions.
    - Ask for observations and reactions.
    - Ask for areas that are not readily understood.
    - Ask if personal experiences support or contradict the content.
4. Have a discussion about the different mental skills and physical skills that lead to better and safer cornering.

Learning Activity C

1. Hand out copies of Cornering Supplement #2 "Traction"
2. Using small groups, divide the content by having each group read a few paragraphs and report on facts and information they find meaning for safe cornering.
3. Some questions to be answered include:
    a. What is coefficient of friction?
    b. What factors make up coefficient of friction, and how can each affect cornering?
    c. What is the purpose of tire tread?
    d. Do larger tires provide more traction?
    e. Name and explain the three "accelerations" and the potential effects on cornering.
    f. Why can a negative slope cause more cornering problems than a positive slope?

Learning Activity D

1. Hand out copies of Cornering Supplement #3 "Cornering."
2. Using small groups divide the content by having each group read a few paragraphs and report on facts and information they find meaningful for safe cornering. (Note: In 2001 as part of its Rider Education and Training System and new curricular products, MSF introduced a new way to approach the decision-making process of motorcyclists. In older curricula, the phrase Search, Identify, Predict, Decide, Execute (SIPDE) was used in the basic course and Search-Predict-Act was used in the experienced rider course. Newer curricula use Search, Evaluate, and Execute (SEE).
3. Some questions to be answered include:
    a. What is the 4-step process for cornering?
    b. What 2 general things must a rider decide when approaching a corner?
    c. How far ahead should a rider's line of sight be?
    d. What is "staying wide" and when should it be used?
    e. Why is it wise to minimize the amount of side force used when cornering?
    f. Define apex.
    g. Draw an increasing radius turn and a decreasing radius turn, and mark where the apex is for each.

h. When is the "greatest practical radius" (safest) achieved?
i. What are the 3 speeds related to cornering, and provide an example of each?
j. Which of the 3 speeds is most critical and why?
k. What are some factors in determining an appropriate entry speed?
l. What are some "worst-case scenarios" that may occur in cornering?
m. Why should a rider keep her/his eyes up and looking through a curve?
n. Why should the eyes be kept level when negotiating a curve?
o. How is lean controlled?
p. How effective is body weight shift in initiating lean?
q. What 2 factors is the "roll" part of the cornering technique based upon?
r. How could an abrupt deceleration in a hard curve cause skidding of either the front or rear tire?
s. Why should a roll-on through a curve be gentle?

Learning Activity E

1. Hand out copies of Cornering Supplement #4 "Leaning In and Leaning Out."
2. Using small groups divide the content by having each group read a few paragraphs and report on facts and information they find meaningful for safe cornering.
3. Some questions to be answered include:
   a. In normal turns, where are the knees to be placed and how should a rider lean?
   b. In what kind of situations is "leaning out" (counterbalancing) advisable?
   c. What is the most typical problem in making highway-speed turns?
   d. Why is the technique of "leaning in" potentially helpful in cornering?
   e. Does leaning in or leaning out have any direct effect on the amount of traction available? Why or why not?
   f. Why use leaning out or leaning in?

Learning Activity F

1. Hand out copies of Cornering Supplement #5 "*Motorcycling Excellence* Chapter 14 "Cornering"
2. Using small groups divide the content by having each group read a few paragraphs and report on facts and information they find meaningful for safe cornering.
3. Some questions to be answered include:
   a. What 2 decisions does a rider face when preparing to negotiate a curve?
   b. What is the difference between a sharp corner and a wide sweeper?
   c. What are some questions a rider should ask when preparing to negotiate a curve?
   d. An aggressive search pattern means to have how many seconds of visual lead?
   e. What does "staying wide" refer to and what is the advantage in using this technique?
   f. Cornering force is dependent on what 2 primary variables?
   g. Why is choosing a good apex important?
   h. What type of curve is most challenging regarding proper technique?
   i. What technique should be used in a blind curve?
   j. What is meant by "*upper limit*" on your entry speed?
   k. In cornering, why keep your eyes level with the horizon?
   l. What is the most effective way to initiate lean?
   m. Rolling on the throttle, within certain limits, in a curve has what benefits?
   n. What are some limits to the roll-on?
   o. What negative effects are produced by sudden shifts in tire loading or power?
   p. How does an off-camber surface affect cornering?
   q. What is the goal of using proper cornering techniques?

Learning Activity G

1. Hand out copies of Cornering Supplement #6 "*Motorcycling Excellence* Chapter 15 "Low-and-High Speed Turning."
2. Using small groups divide the content by having each group read a few paragraphs and report on facts and information they find meaningful for safe cornering.
3. Some questions to be answered include:

a. How does a ride reduce the turning radius of a low-speed, tight turn?
b. What 2 forces must offset each other in a steady, low-speed turn?
c. What 3 techniques may result in smoother overall control in slow-speed, tight turns?
d. What does "leaning out" or counterbalancing accomplish in a low-speed turn?
e. In a highway-speed turn, how does a rider get a more effective lean angle without slowing down?
f. How does a rider eliminate needing fancy riding techniques if cornering too fast?
g. To deal with unpredictable conditions when cornering, what must riders maintain?
h. Why doesn't leaning in or leaning out have any effect on the amount of traction available in cornering?
i. Is it possible to corner faster than traction will allow?

Evaluation

Facilitation Guide Attachment I is for the facilitator(s).
Facilitation Guide Attachment II is for participants.

Motorcycle Safety Foundation

Draft document 11-17-04

Mini-Module Facilitator Guide

Introduction

This Guide is designed to provide a basic template for using the Motorcycle Safety Foundation (MSF) Mini-Modules in conducting training or discussion activities. These mini-modules are designed to be short, single-topic learning experiences that promote safe and responsible riding practices. There is flexibility designed into these mini-modules, that is, a facilitator may plan activities that takes into consideration a variety of variables such as time allotment, size of a group, experience of the group, motivation of the group, availability of resources, capability of the facilitator, etc.

Purpose

The purpose of these mini-modules is to provide safety renewal opportunities for motorcyclists. Participants should possess basic motorcycle skills and be interested in discovering ways to make motorcycling safer and more enjoyable. Although these mini-modules are knowledge based, they are intended to provide a framework to enhance safety renewal and diligence toward safe riding practices. Knowledge alone isn't necessarily the answer to motorcycle crashes, but a sound knowledge base coupled with wise decision-making can improve safety. It is often said that motorcyclist safety is more a skill of the eyes and mind than of the hands and feet, and these modules provide an opportunity to improved safety related decisions. Facilitators should keep in mind the following concepts when conducting mini-modules:

- Motorcycle crashes are not usually caused by a single factor but rather by a combination of factors, and a rider must constantly be alert to evaluate situations to reduce overall risk as well as moment-to-moment risk.
- A good rider is defined a one who constantly reduces the risk factors personally introduced into the traffic mix. This acknowledges that although crashes may include factors introduced by others or by road and traffic conditions, it's important for a rider to control personal risk factors.
- A rider reduces factors by using a good strategy to maintain adequate time and space safety margins, and to allow for a margin of error regarding speed, lane placement or combination of factors. The strategy recommended by the Motorcycle Safety Foundation is Search/Evaluate/Execute, or S.E.E. A rider should use good eye lead times. This means to maintain at least a two-second following distance, a four-second distance for stationary objects to allow for braking and/or swerving maneuvers (four seconds corresponds to total stopping distance), and a 12-second anticipated view to anticipate factors in plenty of time to take action.

- A rider reduces risk because he or she wants to. It's simply a decision to be a smarter rider and do something other than stupid (such as corner too fast, follow too close, bust through intersections, stunt in traffic, be inattentive, wear less than adequate protective gear, ride impaired, etc.).
- The primary challenge to stay safe while riding is to make effective decisions that allow situations to be managed. This means to maintain self-control and stay within personally decided margins of safety.

These concepts are part of every mini-module. Although each mini-module is self-contained and primarily a content-related activity, each session should address the implications for personal decisions that are made to ensure one's own safety as well as the safety of others.

Mini-Module Considerations

When using mini-modules, it is important to consider the following:

1. Facilitators should be competent, safety-minded riders who can effectively lead a group discussion.
2. Facilitators should be familiar with the principles of safety and risk management, adult and learner-centered techniques, as well as motor skills principles if actual on-cycle activities are conducted.
3. Facilitators should be Motorcycle Safety Foundation certified RiderCoaches.
4. Facilitators should be familiar with the content of the Motorcycle Safety Foundation Basic *RiderCourse* (BRC) Rider Handbook as well the ERC Suite Rider Classroom Cards. (Note: Portions of these materials may be copied for use in these Mini-Modules for use as handout material.)
5. Facilitators should have access to the training materials suggested in each mini-module.
6. A function of a facilitator is to keep the group(s) on target and on time, and to ensure activities are meaningful.
7. A function of a facilitator is to ensure that materials and information are correct and accurate.
8. Any riding activities must include a waiver signed by participants, verification of insurance and a motorcycle pre-ride inspection. Also, riders should be pre-qualified to ensure they possess minimum skills to complete any riding activities.
9. At no time during actual riding activities should there be any blatant risky activities, such as stunting or showing off, allowed. Effective space cushions should exist at all times.
10. Facilitators should be adept at conducting small group learning activities.
11. Each mini-module is designed to be a brief seminar or discussion that addresses safety and motorcycling.
12. Although there is a general time line suggested, the format and length of each mini-module is open and flexible to allow for the best use of time in a variety of circumstances.

13. Facilitators should be provided time to prepare mini-module learning activities to ensure effectiveness, efficiency and desired outcomes. This includes a complete review of materials to ensure familiarity and understanding of the content.
14. A facilitator should be a considered a rider who sets a good example and who puts into practice the recommendations and tips that produce safe riding decisions and actions.
15. Facilitators may contact the Training Systems at the Motorcycle Safety Foundation for further information. (training-systems@msf-usa.org or 949.727.3327, ext. 3061.

Mini-Module Design

Each mini-module has the same basic template, that is, each one has the same look. This is to help a facilitator organize training or discussion sessions effectively and efficiently. Each mini-module has eight sections, and each is described below:

Topic and General Time

This section provides the name of the topic or issue to be discussed. Only one topic is used for each mini-module to keep the time for discussion reasonable. Also provided is a general time line to use in facilitating group discussions. The time noted is for each learning activity within the mini-module, and may vary significantly depending on the size of the group and time devoted to a session.

General Objective

This section provides the overall objective or goal of the mini-module. It is stated in broad terms and sets the stage to achieve specific, supporting objectives using a variety of procedures and techniques.

Specific Objectives

This section lists the specific or enabling objectives that support the general objective. These are stated in behavioral terms to promote attainment of specific outcomes. The Specific Objectives along with Related Terms and Learning Activities form the content of each mini-module. Additional objectives and content may be considered.

Materials and Items Needed

This section names the common materials that may be necessary to conduct a specific mini-module. Not all items listed are necessarily needed, but the information provided will allow a facilitator to plan activities specific to a particular group. Some of these materials may be handouts or props, and some may be training aids or articles that have been reproduced from a variety of resources. A facilitator may wish to add items that are not on the list that may be valuable in contributing to the quality of the mini-module. In some cases, there is material that may be used at another time but devoted to the same topic. As much as possible, learning activities should be tailored to meet the specific needs and interests of a group and include implications for local riding situations and circumstances.

Related Terms

This section presents common terms associated with the topic. This information is useful as a vocabulary list in preparing for or conducting a mini-module. Additional terms may be added, and many will be shared with other topics.

Learning Activities

This section provides a menu of learning activities and action steps for conducting a mini-module. These may be modified to improve effectiveness and efficiency, or to make best use of materials that are available. One learning activity may be used for each meeting (several may be combined), or a different learning activity could be used in separate meetings. A facilitator should choose learning activities that are most meaningful for a particular group, and consider what is personally the most comfortable method of presentation or interaction.

Evaluation

This section refers to two evaluation forms that are attached to this Facilitator Guide. Attachment I is for a facilitator to complete and Attachment II is for riders to complete. Both forms should be completed and returned (copies are OK) to MSF at:

Motorcycle Safety Foundation
Training Systems
2 Jenner Street, Suite 150
Irvine, CA 92618

MSF Mini-Module Evaluation Form (for Facilitators)

Title of Mini-Module ______________________________ Date ____________

Length of time used for conducting the Mini-Module ___________

Time needed for Mini-Module preparation __________________

Number of riders/visitors in attendance ________________

Are you a currently certified MSF RiderCoach? _________

Please answer the following questions. Use the back of this sheet if necessary.

1. What were the best part(s) and weakest part(s) of the Mini-module?

2. What should be done to improve the Mini-Module Facilitator's Guide?

3. What should be done to improve the structure and learning activities of the Mini-Module itself?

MSF Mini-Module Presentation – Rider Feedback & Evaluation Form

Directions: Please respond with comments. No signature is necessary.

Title or Topic of Mini-Module ________________________________ ***Date*** ___________

The information found to be most useful:

____

____

____

What I wish I would have received:

____

____

____

CONTENT	**LOW**				**HIGH**
Overall rating	**1**	**2**	**3**	**4**	**5**
Content was what I expected	**1**	**2**	**3**	**4**	**5**
Found value in the resource materials	**1**	**2**	**3**	**4**	**5**
Content was well organized	**1**	**2**	**3**	**4**	**5**

Comments:____

____

____

FACILITATOR(S)	**LOW**				**HIGH**
Overall Rating	**1**	**2**	**3**	**4**	**5**
Demonstrated knowledge of content	**1**	**2**	**3**	**4**	**5**
Facilitator(s) interest in participants	**1**	**2**	**3**	**4**	**5**

Comments:____

____

____

ACTIVITIES	**LOW**				**HIGH**
Effectiveness	**1**	**2**	**3**	**4**	**5**
Organized & well prepared	**1**	**2**	**3**	**4**	**5**

Comments:____

____

____

AS A PARTICIPANT	**LOW**				**HIGH**
I was fully active and engaged in Participating	**1**	**2**	**3**	**4**	**5**
My co-participants were actively Involved and supportive	**1**	**2**	**3**	**4**	**5**

Comments:____

____

____

OTHER COMMENTS ON BACK

Facilitator Notes

Cornering Supplement #1

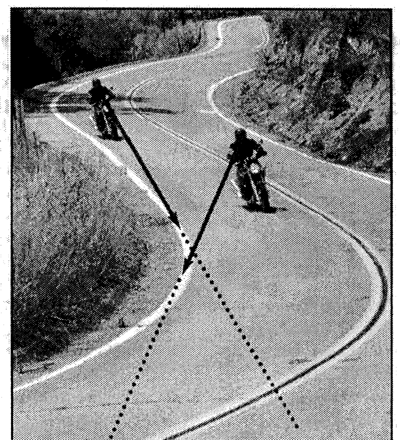
SAFE cycling

Spring 2004

Where Should Riders Look?

The Basic *RiderCourse*℠ (BRC) and the Experienced *RiderCourse* Suite℠ (ERC Suite), along with other MSF Rider Education and Training Systems (RETS) training opportunities, stress the importance of riders keeping their head and eyes up when they are riding, and especially to look through turns when cornering. It is mentioned as an evaluation point in nearly all of the riding exercises.

But what does "keep head and eyes up" and "look through a turn" mean and how should riders be coached on the range? Let's look at what the research community has discovered about the use of eyes when operating a vehicle. Be aware that most scientific research on the visual process uses car driving as the basis of experimentation. The head-based video system used to determine scientifically where a driver looks would be far too cumbersome to be placed on the head of a helmeted rider.



Studies show that the gaze of a rider is directed to the tangent point of the curve about 80 percent of the time. As the rider's position in the curve changes, so does the tangent point.

First You See It

Some important research findings about vision and operating a motor vehicle were discussed in Johnson & Dark[1]. They confirmed that

- visual information is the primary source of information when driving;
- attention is important in perceiving things clearly and accurately.

Information available from peripheral vision, though still in the field of vision, is scarcely processed or not processed at all. Johnson and Dark point out that attention is a necessary part of developing a visual inspection strategy, especially in planning eye movements.

Eye Movement

Saccadic eye movements are the natural, rapid, irregular movements of the eye as it changes focus moving from one point to another. Crundall and Underwood[2] compared the differences in the focus of attention between novice and experienced drivers. The results of their investigations suggested that when experienced drivers are driving through curves or on demanding roadways, their eyes don't fixate on an object very often or for very long periods. The fixations being referred to are not target fixations where the eyes fixate for several moments. They refer to brief assessments of driving situations that correspond to saccadic eye movements.

Roving Eyes

Recarte and Nunes[3] found that in spite of the importance of being alert and constantly scanning for potential problems, very little research was done regarding eye movements while driving. Some studies used simulated experiences and showed that visual scanning requires a time-sharing strategy. After all, the eye cannot look at two locations at the same time.

They also mention that if eye movements reflect the amount of attention that is devoted to objects or locations, then a decrease of available attention should cause a reduction of the useful field of view, which could be relevant to safety. The lesson here is that when riding, the eyes should inspect the environment while at the same time evaluating significance, so the eyes must not fixate too long on any one spot. This is in alignment with *RiderCourse* coaching to keep the eyes moving to evaluate the many factors that could affect speed, lane position, or path of travel. More than ever we know that the eyes don't necessarily tell us what we see—we tell our eyes what to look for.

Off on a Tangent

While investigating how to engineer self-steering vehicles, Land and Lee[4] looked at the human visual process and found little direct information to link steering performance to where the driver was looking. Using recordings of steering-wheel angle and driver's gaze direction during a series of drives along a winding road, they found that drivers rely on the tangent point on the inside of each curve, seeking this point before each bend and returning to it throughout the bend. The gaze of the drivers was directed to the tangent point about 80 percent of the time, demonstrating the importance of this visual clue. It follows that a motorcycle operator would also find the tangent point of the curve to be quite meaningful.

Experience Does Matter

Summala and others[5] compared how novice and experi-

continued on page 8

Where Should Riders Look? (cont.)

continued from page 1

enced drivers maintain their position in a lane ("lane keeping") using peripheral vision. Their experiments supported the hypothesis that novices need central vision (at first) for lane keeping, but with practice learn to stay in a lane using more peripheral vision. As skills become habits, considerably less thought is necessary for lane keeping.

This means that RiderCoaches should avoid having novices look too far ahead in turning and cornering while they are still learning basic control responses. RiderCoaches should adjust their coaching to accommodate the various skill and perception levels of riders.

Encourage Aggressive Use of the Eyes

Development of the MSF RETS rests heavily on principles of human learning and development. Curriculum development, field-testing, and the ultimate release of a formal course of instruction must be based on the principles of how people learn and develop perceptual and motor skills. Adherence to principles and their proper application forms the basis for decision making in terms of curriculum content and instructional methods. RiderCoaches should have a basic understanding of visual processes so they can more effectively coach riders to develop the habits of the eyes and mind that are necessary for reducing risk and enjoying the ride.

During both classroom and range sessions, RiderCoaches should encourage the aggressive use of the eyes to recognize a hazardous situation or a potential problem and be familiar with the three eye lead times (see the box at right).

> **Visual Lead Perspective**
>
> ***Following Distance*** The two-second following distance takes into account perception time (determining the need to stop) and reaction time (reacting with the brake controls). It is a minimum following distance that works at any speed when the braking distance of a vehicle and the vehicle it is following are generally the same.
>
> ***Immediate Path*** The four-second immediate path generally corresponds to total stopping distance and provides the distance needed for an escape should a traffic or roadway problem suddenly develop. If skilled riders have four seconds of space to the front or sides in which to stop or maneuver, they are likely to have the time (and space safety margin) to avoid a crash.
>
> ***Anticipated Path*** The twelve-second anticipated path provides enough time for a rider to assess potential factors that could interact to increase risk.

Go Where You Look?

Does a motorcycle go where its rider looks? Of course not. If this were true, a rider could simply avoid a crash by looking elsewhere. If this were literally true, a rider would swerve every time a blind spot was checked or a rider looked at beautiful scenery off to the side. To cause a motorcycle to move from a straight path of travel, there must normally be some physical input—the handlebars must be moved.

The science of motor skills development suggests that learners develop gross psychomotor skills first (the learner consciously tells the nerves and muscles what to do and they react) followed by the development of finer perceptual motor skills (the brain tells the muscles what to do without any conscious thought on the rider's part). As a rider's gross inputs lead to improved accuracy, the brain can then consider higher-order processes such as evaluating the interaction of factors further ahead.

Target Fixation

What's the difference between target fixation and looking where you want to go? Target fixation is when you look at a fixed point for more than a couple of seconds. This may narrow the useful field of view and in extreme cases can become inattentional blindness.

When riders turn or corner on the range, those who fixate on a given point in the distance might miss certain factors that are important for safety, such as surface conditions or proper path of travel. Riders on the street might miss objects in their immediate path of travel. A rider should look where he is going but avoid target fixation by moving his eyes throughout an intended path of travel. Riders should also realize that mental attention increases their useful field of view.

Turning and Cornering

Where should a rider look when turning and cornering? From the visual lead perspective, at least four seconds ahead in the intended path. This is the minimum amount of time necessary to straighten and brake in the best of conditions, but of course more time and space is better.

Ideally riders would be able to look, with short and frequent glances, 12 seconds ahead through a corner to evaluate the roadway and traffic factors that could affect speed, lane position, or path of travel. Although this may be possible on a motorcycle range, common roadway environments may not allow a full 12-second search because of factors such as natural terrain, surface obstacles, darkness, and traffic.

As riders practice their skills on the range, they should be encouraged not to stare at any one cone or any one point in their path of travel (target fixation). A rider must develop the ability to gather important information and transfer it into proper and skillfully-timed motor skills. RiderCoaches should encourage motorcyclists to keep their head and eyes up and look through turns. Although riders should pay attention to where they are going, they should not be led to believe that a motorcycle simply goes where they look.

Evaluate Your Own Riding

Riding a motorcycle safely is more a skill of the eyes and mind than of the hands and feet. The mental aspect of effectively and efficiently negotiating the traffic jungle and the variety of riding environments is the cornerstone of safe and responsible riding.

RiderCoaches may be able to gain valuable insight into their personal riding habits and techniques by reflecting on what they actually do when cornering. When negotiating corners on your next ride, notice where your attention is. How far do you look through a turn? Do you spend your time looking at the end of the curve or at the tangent point? Is it the same for all curves or do you adjust for variations? How do you divide your attention between surface conditions and path of travel? How often do you catch yourself fixating? Can you tell the difference in your awareness when

continued on next page

Where Should Riders Look? (cont.)

you tell your eyes what to look for instead of relying on your eyes to pick up important factors?

Check what you do when performing *RiderCourse* exercise demonstrations to see if your eye movements match up. One of the best exercises in which to check these techniques is ERC Suite Exercise 9, Multiple Curves, where it is necessary to combine the good visual process of keeping the head up and eyes moving while maintaining a proper path of travel and lane position.

Make Your Coaching More Meaningful

Coaching is powerful when riders are provided timely tips that boost them to accomplish a mental or physical skill they otherwise would not learn on their own. It's what gives riders an advantage in developing motor skills or learning the critical strategies for riding on the road. This is why it is important that RiderCoaches understand the principles of the BRC and know the *whys* and not just the *hows* of safe riding techniques.

For additional information regarding the importance of visual perception and its connection to motor skill development and identifying important clues in traffic, visit the MSF Rider Education and Training System Online Resource Guide (RETSORG). MSF continues to expand this valuable resource in an effort to provide RiderCoach resources to promote a better understanding of the mental and physical skills of safe and responsible motorcycle operation. **SC**

1. Johnson, William A. and Dark, Veronica J. (1996). Selective attention. Annual rev. psychol. 37, 43–75.
2. Crundall, David E. and Underwood, Geoffrey. (1998). Effects of experience and processing demands on visual information acquisition in drivers, Ergonomics. 41(4), 448–458.
3. Recarte, Miguel A. and Nunes, Luis M. (2000). Effects of verbal and spatial—Imagery tasks on eye fixations while driving. Journal of experimental psychology: Applied. 6(1), 31–43.
4. Land M.F. and Lee, D.N. (1994). Where we look when we steer. Nature. 369, 742–743.
5. Summala, Heikki, Nieminen, Tapio, and Punto, Maaret. (1996). Maintaining lane position with peripheral vision during in-vehicle tasks. Human factors. 38(3), 442–451.

TRACTION

The Formula

The subject of traction can be a confusing one, especially to those without a technical background. In general terms it really boils down to a simple basic relationship:

$$F = C_f N$$

This expression is engineer shorthand for saying that the maximum **Friction (F)** between any two materials is the product of two major factors: the first is what engineers call **coefficient of friction (C_f)**; the second is the force pressing the materials together, which is called the **normal force (N)**.

The relationship is a general one that can be used to talk about clutches and brakes as well as tires. To make it relevant to tires, we will simply substitute the words "traction" for "friction" and "tire loading" for "force."

However, as with any general relationship, it is too simplistic to adequately explain everything about what happens where the rubber meets the road. Nonetheless, it is a good place to start this discussion, because it establishes the basis for understanding most of what the word "traction" means to us. We'll cover its limitations as we go.

Coefficient of Friction

You can think of a coefficient of friction as simply a measure of the potential for traction. It really describes the nature of the tire (its design, compound, temperature, and age), the nature of the road surface (its material, roughness, condition, etc.), and the degree to which the tire is being stressed (the load on the tire, whether it is rolling or sliding, etc.). Let's look at the most important factors affecting the potential for traction.

Tire Compound: Generally, the softer the rubber, the greater the potential for traction. However, there is another truth about rubber: the softer it is, the more rapidly it wears and the more it will flex under stress. So, to make a realistic street tire, there must be some compromises. Ongoing improvements in carcass design, rubber compounding, etc., have significantly reduced the effects of such compromises. For example, the traditional belief that high mileage means low grip or vice versa is far less true today than it once was. Modern motorcycle tires perform amazingly well. Nonetheless, even the best of them sacrifice ultimate traction for other considerations, such as long life and stability.

It is also wise to remember that rubber hardens with age and as the result of flexing. So all tires, including those intended for sport riding, lose traction potential with age.

Tire Temperature: Rubber is not as soft and pliable when it is cold as when it is warm. Each compound functions best at some design temperature, so it is important to get the tires to that temperature before expecting maximum traction potential. The natural flexing of the tire produces the heat necessary to warm the tire, so riding moderately for a few miles is all that's necessary to get the tires into their design temperature range. There is a limit, however, to the benefits of warming the tires. If they get too hot, they wear rapidly and lose traction potential. Maintaining proper tire pressure and remaining within their load/speed ratings are the keys to preventing overheating. These two factors limit the amount of flexing that occurs as the tire rolls.

Tire Tread: The purpose of the tread pattern is to give better traction on wet surfaces. It does this by providing channels for water to escape from the contact patch (the area of the tire touching the road) and, thus, delay the onset of hydroplaning.

Hydroplaning occurs when the water can't get out of the way of the advancing tire. It literally lifts the tire from the road surface. It is similar to what happens when a speed boat (a hydroplane) or a water ski is moving fast enough to skim along on the surface of the water. One reason why tire manufacturers recommend that a tire be replaced while there is still $^1/_{16}$" to $^3/_{32}$" of tread remaining is that tires worn beyond this point are not safe in the rain — even though the tread pattern remains visible. The grooves are not deep enough to channel away sufficient water to prevent hydroplaning at even moderate speeds.

The tread pattern has very little to do with dry traction directly, but it can affect heating rate, wear rate, stability, and control. In general, the larger the tread blocks (the greater the space between the grooves) and the narrower the grooves, the greater the tread life and stability — at the expense of wet traction. The wider the grooves and the smaller the tread blocks, the greater the wet traction — at the expense of tread life and stability. As with compound, though, technical advances within the tire have lessened the effects of tread pattern as a compromise between conflicting goals.

Before leaving the subject of the tread, we must address the size of the contact patch and how it relates to the traction available. Notice that our general traction formula does not mention anything about the size of the contact patch. Does this mean that the amount of rubber on the road has no effect on the amount of traction available? Unfortunately, there is no simple answer to this question, except to say, "It depends."

First, consider the friction between two sliding, hard, dry surfaces (metals, plastics, etc.). Such materials exhibit what is known as "plastic" deformation. For such materials, even highly polished, "perfectly" smooth surfaces are microscopically irregular. Their real area of contact is between these minute irregularities and is essentially independent of the size of the apparent "contact" patch. Instead, it is proportional to the ratio between the load on the surfaces and the yield strength of the materials. This friction mechanism is commonly called "adhesive friction"or simply "adhesion." But tires are made of rubber, a material that exhibits "elastic" deformation. What happens to the coefficient of friction when one of the surfaces is rubber?

As with harder materials, adhesion is a major contributor to the friction between rubber and the road surface. In fact, so long as there is no significant sliding between the rubber and the surface, adhesion remains the dominant factor. On the street, the normal condition is for the tires to roll without sliding. Therefore, the dominant friction mechanism is adhesion, and the size of the contact patch has little to do with the maximum traction available.

But once a tire begins to slide relative to the surface, the situation becomes more complex. The sliding coefficient of friction is dependent on three factors in addition to the adhesive component we've already described: deformation under stress, viscous behavior, and resistance to tearing. These factors are interrelated, and, unlike adhesion, they depend strongly on the size of the contact patch.

The **adhesive friction** component varies with sliding speed and temperature. In practice, sliding friction often decreases as sliding speed increases. The effect is complicated, however, by the fact that the tire-road slip causes heating.

Since rubber can be readily **deformed** under high loads, the **actual contact area** is no longer proportional to the load but to the $^{2/3}$ power of the load. This means that the coefficient of friction is not constant, but is proportional to

$$(\text{average contact pressure})^{2/3}.$$

This is also reflected in the well-known experimental relationship that the coefficient of friction μ is proportional to

$$\left(\frac{1}{\text{rubber hardness}}\right)^{2/3}$$

on dry surfaces.

The **viscous behavior** of the rubber manifests itself in the friction process as a retardation force (or damping loss) as the rubber slides over the bumps or protuberances of an uneven surface. The bumps produce vibrations in the rubber at frequencies that are related to the sliding speed and the texture of the road surface. A well-known manifestation is the high-frequency squeal of sliding tires.

Finally, the **tear** component of rubber friction involves the tearing of minute particles from the rubber surface by high traction and contact stresses, causing fracture in the rubber. Very high values of μ can be explained by this process.

Typical μ values in this respect would be 0.8 μ for truck tires and 2.0 μ for drag-racing tires.

Rubber is an elastic solid, so the sliding friction on dry surfaces involves processes whose effectiveness is related to the "amount of rubber on the road." This explanation on the traction of tires is not intended to create the belief that a larger contact patch will always provide a higher traction level, only that it is a factor to consider.

For example, the area of contact affects heating rates, stability, resistance to hydroplaning and the importance of small defects or spots of lubrication on the surface. In some cases (like with a small patch of oil), a large contact patch can have a beneficial effect on traction. In others (like with hyroplaning), it can be harmful.

There is a popular belief that fitting a larger tire will always provide a larger footprint, and therefore higher traction. That is not necessarily so because other factors, such as size of the rim, need to be considered. Rim size has a direct influence on the resulting size of footprint.

In racing, a big, fat tire with a large contact patch provides a high level of traction. The large contact patch permits the use of a soft, sticky tread compound. Such a compound in a smaller contact patch under the high stresses of racing would cause the rubber to overheat, tear and degrade to a level that would significantly lower traction.

Tires are designed as a total unit. Their size, carcass configuration, compounds, size of contact patch, etc., are blended to provide the optimum balance of performance and intended use. Traction is a key consideration in this performance package.

Road Surface: The surface material (asphalt, concrete, dirt, paint, ice) and the presence of lubricating materials (water, oil, antifreeze, leaves, sand, mud) combine to affect the potential for traction. It is difficult to make many valid general statements when there are so many variables involved. Dry, coarse concrete is better than wet, smooth ice; but between these extremes you must rely on common sense and trial-and-error experience to estimate the surface's traction potential. Here is where an effective riding strategy like SEARCH—PREDICT—ACT comes into the traction management concept.

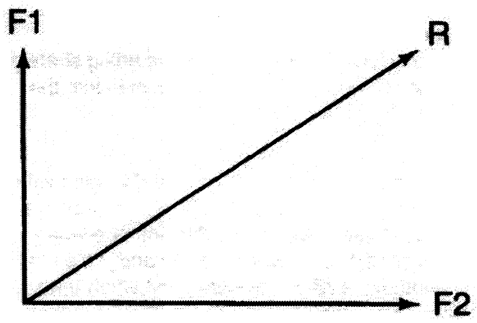
As you can see, the potential for traction or coefficient of friction is a continually changing value that is difficult to predict. Note also that there are two distinct values for the coefficient: one when there is no sliding between the tire and the surface and another, significantly lower, one when there is sliding. This is why a skidding tire produces less traction than a rolling one. Maintaining properly inflated tires in good condition and using proper visual habits to detect surface problems early to avoid skids are the rider's principal means of controlling or managing this aspect of traction.

Tire Loading: This brings us to normal tire loading, the other principal factor in the amount of traction available. Tire loading is what determines just how much of the potential traction discussed above is actually achieved. It's also the one over which the rider has the most control from one moment to the next, because it is affected by speed, turning radius, the rider's throttle and brake techniques, etc.

Tire loading is the term engineers use for the total force that the tires exert on the road surface. Normal tire loading is the component of total tire loading that acts to push the contact patch into the surface. (Normal in this sense is technical jargon meaning perpendicular, or at 90°, to the surface.) Notice the word *component* in the earlier sentence. It is an important word. We need to ensure that we understand the concepts of "component" and "resultant forces."

Diagram 1 illustrates this concept. The arrows in this diagram represent forces acting on or through a point on some physical object. The length of the arrows is proportional to the magnitude of the forces. Their orientation represents the direction in which the forces are acting.

Diagram 1: Component and Resultant Forces

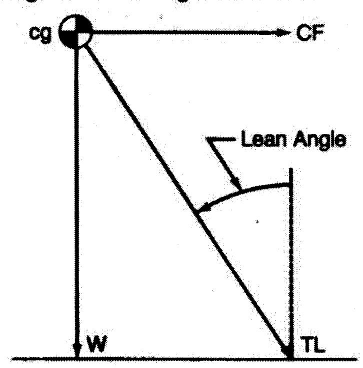


Forces F1 and F2 are two components, of the single resultant force, R. The resultant alone would affect the object exactly as the two components acting simultaneously. In other words, the resultant is the equivalent of its components and vice versa. At times it is easier to see what's going on by thinking of the components; at other times it is simpler to think of the single resultant force. The important idea here is that any set of forces acting through a single point can be represented by a single resultant force, and any single force can be broken down into a set of component forces that are equivalent in overall effect. With this idea in mind, we can now get back to our subject.

Tire loading is the resultant force produced by several components (weight, centrifugal force, etc.). To understand its relationship to traction, we must break this resultant force down into two components. One acts perpendicular or at 90° to the road surface, and the other acts parallel to the road surface. Remember, only the component of tire loading that acts perpendicular to the surface produces traction.

The other, parallel, component of total tire loading represents a need for traction. **Diagram 2** (following) illustrates this relationship in a turn on a level surface.

Diagram 2: Turning on a Level Surface



The weight **(W)** acts vertically downward and the centrifugal force **(CF)** acts horizontally to the right. Both forces act through what is known as the center of gravity **(cg)**. The resultant of these two components, tire loading **(TL)**, also acts through the cg at an angle (measured from vertical) known to us riders as the lean angle. In this situation, only the weight acts perpendicular to the surface, so it is the only factor that acts to produce traction. Notice also that since the weight doesn't change simply because the bike is leaning, the total traction remains exactly the same as it would be if the bike were going straight (at zero lean angle). Many riders believe that there is less traction when the bike is leaned over, so this may be news to them.

Level Surfaces

Of course, remember that we are dealing with an absolutely level surface here, and there aren't many such places out on actual streets and highways. What happens if the surface slopes or inclines? That's a very good question, and we'll get into that in a few minutes. But, for now, let's stay with the level or nearly-level aspect to discuss some factors that affect total tire loading and its distribution between the tires:

- When the bike is at rest on a level surface, the tire loading is simply the weight of the bike, rider(s), and cargo. The proportion of the total weight supported by each tire is determined by the center of gravity relative to the contact patches. Think of this as the basic tire-loading distribution, say 50:50 or 48:52, front to rear.

■ Accelerations that produce an increase in speed cause the distribution of the tire loading to shift toward the rear. The load on the rear tire increases, while the load on the front tire decreases. The effect is proportional to the magnitude of the acceleration; the harder you accelerate, the greater the transfer. The extreme case is known as a "wheelie." Note: The total tire loading doesn't change, just the distribution. If there is no wheel spin due to excess power, then total traction also remains the same, because the weight and the friction coefficient do not change.

■ Similarly, accelerations that produce a decrease in speed (known as "decelerations" in non-technical conversation) cause the distribution of tire loading to shift toward the front. Again, the harder you "decelerate," the greater the transfer. The extreme case is known as a "brakie," "stoppie," "nose stand," etc. Total tire loading doesn't change, and if there is no skidding due to overbraking, total traction is unchanged.

■ Vertical accelerations due to dips and bumps in the road result in momentary changes (both increases and decreases) in the tire loading and traction. It is the job of the bike's suspension to minimize these effects by absorbing part of the energy and by damping any bouncing tendencies. These effects are more severe in turns, because the suspension is designed to absorb such disturbances only in the plane of the wheels.

■ So long as the motorcycle is under enough power to at least maintain speed, aerodynamic drag force and the driving force necessary to overcome it act together to shift the distribution of tire loading from the front to the rear. Total tire loading and traction are not affected by this factor, but they can be if there is any net aerodynamic lift or downforce. These aerodynamic effects increase as the square of the speed: at 60 mph they're four times what they are at 30 mph.

■ The brakes and the power train produce torque-reaction forces. The forces produce accelerations of the suspension components, which result in momentary changes in the loading of the affected tire. Perhaps the best known and most obvious of these is the so-called "shaft-drive effect" in which the rear suspension extends or retracts as engine power is added or removed. The brakes can produce similar effects, depending on the design of the brakes and how they are mounted relative to the suspension components. These effects are generally rather small and very brief, but they can sometimes make the difference between a rolling tire and a skidding tire in the manner of the "last straw." Smooth throttle and brake techniques virtually eliminate them as significant factors.

Non-Level Surfaces

Now we can get back to our earlier question. What happens if the surface slopes or inclines? The answer to that one is a bit involved, because each case is different, depending on the orientation of the surface to the direction of travel.

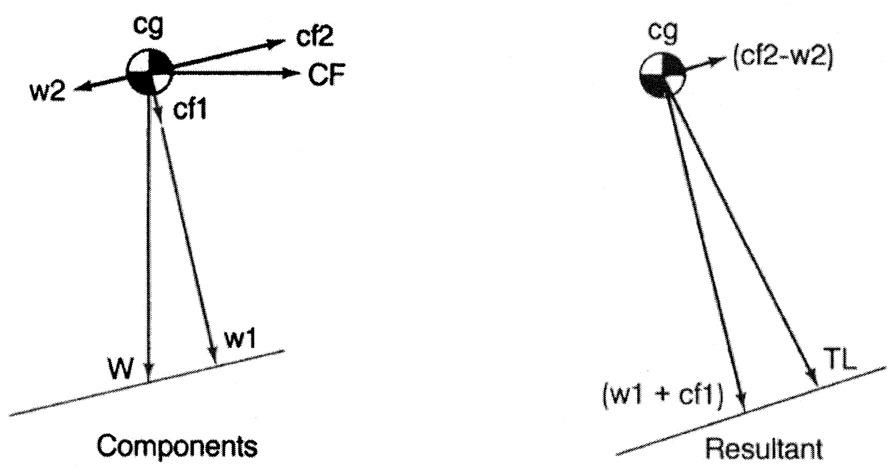
To begin, let's look at a turn on a "banked" or positive-slope surface. Let's assume that we have the same bike making the same turn (speed and radius) as before. The weight is the same, and since the speed and radius are the same, the centrifugal force is the same. Therefore, the resultant total tire loading is the same. But what about the traction?

In **Diagram 3** (following page), each of the two major components — weight **(W)** and centrifugal force **(CF)** — is broken down into subcomponents that act perpendicular to the surface **(w1 and cf1)** and parallel to the surface **(w2 and cf2)**. These subcomponents must be added (or subtracted if they act in opposite directions) to come up with the net perpendicular and parallel components of tire loading. This result is shown on the right, where the resultant tire loading **(TL)** is shown with the net perpendicular component **(w1 + cf1)** and the net parallel component **(cf2 - w2)**.

On any non-level surface, the perpendicular component due to weight alone is reduced. This includes going directly up, down, and across hills. The steeper the slope, the greater the loss of total traction due to the weight. But in a turn

Traction

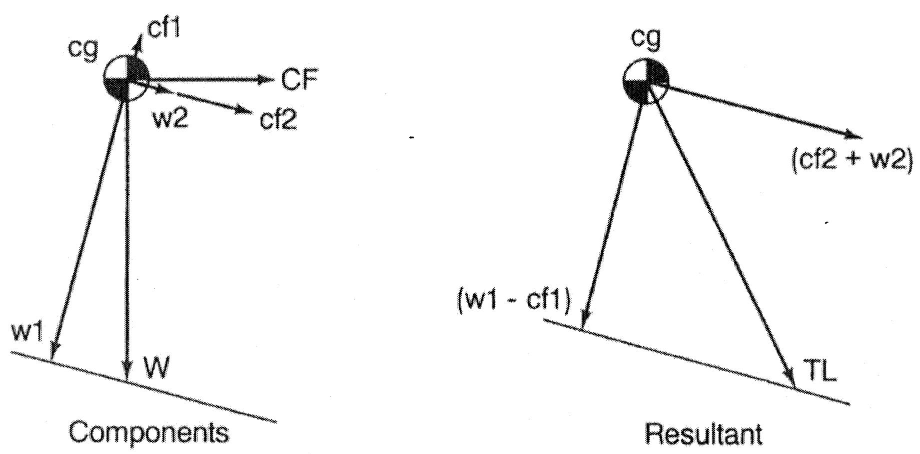
Diagram 3: Turning on a Surface with a Positive Slope



with positive slope, there is a component of centrifugal force that compensates for this loss in traction by adding a perpendicular component of its own. Also, notice that the parallel components **(cf2 & w2)** act in opposing directions so that the demand for traction is reduced. Therefore, the banked turn is good for two reasons related to traction.

With negative slope, shown below in **Diagram 4**, the situation is not so good. The weight is still producing less traction, but now the centrifugal force makes things even worse by subtracting from the traction. Its perpendicular component **(cf1)** acts away from the surface rather than toward it, so the net traction-producing component **(w1 - cf1)** is significantly smaller than in the previous case. Note also that the parallel components **(cf2 & w2)** both act downhill. Therefore, when traction is relatively low, the demand for traction is even higher.

Diagram 4: Turning on a Surface with a Negative Slope



We can make similar analyses for each specific case, but these examples are sufficient to demonstrate the principles and the ideas. It is easy to see the importance of looking well ahead and being alert to changes in road slope, camber, and surface condition, etc., when selecting a line and speed through any corner.

Summary/Bottom Line

Well, that's about it as far as traction goes. It depends on the potential for traction as expressed by the coefficient of friction and on the net force acting to press the contact patch of each tire into the road surface.

The rider's task is to keep both factors as high as possible when the demand for traction is high or to keep the demand for traction at a minimum when traction is likely to be low.

CORNERING

For many riders, cornering is what enjoying motorcycles is all about. For others, it is a necessary evil that is endured only as a means of getting to the next straight section of highway. Regardless of which end of the spectrum a rider places himself, the ability to corner smoothly and safely is a necessary skill. This supplement presents the basics of cornering in more detail than most riders need or care to know about. It is intended, as are all of the technical supplements, to provide you with background information.

SLOW, LOOK, LEAN, and ROLL! That's what we recommend as the procedure for cornering. We will look at each of these in some detail, but before we do that, let's take a minute to put this procedure into the context of riding.

In this course, we discuss the mental activity of riding in terms of SEARCH, PREDICT, and ACT. Our cornering procedure should be thought of as only one example of applying our basic strategy to a specific riding situation. No corner exists independently. The rider has to SEARCH, PREDICT, and ACT his or her way both to the corner and away from it, as well as through the corner itself. So let's begin with the approach to the turn to establish a context for our cornering procedure.

Line of Sight and Speed

> As the rider approaches a turn he or she must decide on two things concerning the corner: an acceptable line and an appropriate speed.

To make these judgments, the rider must first determine what sort of corner it is. Is it a sharp corner or a wide "sweeper"? Is it a single corner or one of a series? Is it of constant radius or does the radius change? Is the road banked properly or is it "off camber"? Are there any surface defects or hazards? Is there conflicting traffic? Can the rider see completely through the corner, or is the line of sight restricted?

That's a lot to find out in a short period of time, and a mistake in any one of them could mean trouble. To gather such information about a corner, the rider must be able to see as much of the corner as possible. Remember what we say in the Riding Strategies discussions about maintaining an aggressive search with a 12-second visual lead. Well, that applies to more than just urban situations. Granted, it may not be possible to always maintain a 12-second line of sight, but the principle remains a valid one. The rider must consciously work to maximize the line of sight.

Notice that there is a subtle difference between the visual activity associated with the SEARCH that occurs as we approach the corner and the LOOK that occurs as part of the cornering procedure. They are certainly related and, in fact, overlap as the transition from the approach to the corner takes place. However, some riders could become confused and think that they should not do any "looking" until they have slowed for the turn.

There is one general rule concerning line of sight in corners: the exit is where you want to go, so the exit is what you need to see. Until you can see the exit, you really have no idea what sort of corner it is and what is going to happen immediately after it. Therefore, if you can't see all the way through the corner to its exit and beyond, then you should "stay wide" and limit your speed until you can. "Staying wide" means keeping as close to the outside as is practical, consistent with roadway and traffic conditions. But what does "limit your speed" mean?

Well, it's sort of like not "overriding your headlight" at night. It means maintaining a speed that will provide time and space to successfully react to situations as they first appear in your field of view. There's more to the subject of speed in turns than this, and we'll get to that shortly.

But for now let's continue on the subject of selecting a path of travel.

One of the principles of traction management is that the rider should try to maximize the amount of traction reserve to ensure that there is traction available to make changes in speed and/or direction should that become necessary. One of the ways to do this is to minimize the amount of side force the tires must generate in a turn. If you'll recall from the Traction Pie Supplement, the cornering force necessary in a turn depends on two variables: speed and turn radius. For any given speed, the greater the turning radius, the smaller the side force and the greater the traction reserve. This means that the rider should choose a line through the corner that tends to maximize the turning radius, again consistent with roadway and traffic conditions.

Apex

And there is one more factor that we need to consider when selecting a path—where to place the apex.

> The apex is the point along the path through the corner that is closest to the inside boundary of the turn. Where it occurs in relation to the geometry of the turn can be very important to the efficiency and smoothness of the line.

To see what the options are regarding the apex, let's begin by considering a simple, constant-radius turn with no obstructions to line of sight. Our traction-management principle of selecting a path with the greatest practical radius tells us that we should begin the turn as far toward the outside as we can, then follow a smooth path that takes us near the inside edge of the turn at its midpoint, then exit the turn as far to the outside as practical. This puts the apex at the center of the turn. We can use this as the reference point for the rest of the discussion.

Apex — Increasing Radius

Next, consider a turn with an increasing radius. This is not a particularly challenging sort of turn for most riders, but they can be set up poorly if an inappropriate apex is chosen. To arrive at the greatest practical radius for this type of turn, you must place the apex prior to the midpoint of the turn; that is, an early apex. A normal or center apex for this type of turn results in an overly sharp initial radius and makes poor use of the extra room available during the last part of the turn.

Apex — Decreasing Radius

The opposite end of the turn spectrum is the decreasing-radius turn. This type of turn is difficult because the tendency is to select a path that produces an apex too early in the turn and requires an adjustment in line and/or speed to prevent running wide at the exit. The greatest practical radius is achieved by using a path that results in an apex which is beyond the center of the turn, a late/delayed apex.

Since the most difficult of these three types of turn is the decreasing radius, it is the prudent prediction that a rider should make when approaching a blind turn. If the rider sets up for a decreasing radius and a late/delayed apex and then discovers a constant or increasing radius as the exit comes into view, this is a pleasant surprise. The late/delayed apex almost always results in greater reserves and more options for the rider to adjust to surprises that are not pleasant. So, in that sense, it is potentially the safest option for any turn.

Apex — Multiple Turns

All of the foregoing discussion concerning apex selection was based on the assumption that there was a single turn to contend with. When one turn leads to another, then the selection of path and apex becomes more complex, and the simple rules discussed above might not result in the best line through the series of corners. Consider, for example, a series of two turns where the first is a constant radius and the second is a decreasing radius. If the rider selects a normal or center apex for the constant-radius section, he winds up in the wrong place to enter the decreasing-radius section. If, instead, the rider sets up a late/delayed apex for the constant-radius section, the rider is in a good place to enter a path with a late/delayed apex for the decreasing radius. This is but one example of the need for the rider to SEARCH well ahead and to PREDICT what is going to happen next before ACTING when it comes to selecting a path and an apex for any turn or series of turns.

Apex — Summary

To summarize, when approaching a turn, the rider should select the path that tends to maximize line of sight until the exit becomes visible and then follow the path that results in the maximum effective turn radius through the exit of the turn. In many cases, the "ideal" path and apex must be modified because roadway and/or traffic conditions preclude using the path with the best line of sight or the maximum turn radius. With this in mind, we can get on to the subject of speed.

3 Speeds for Cornering

It is useful to think in terms of three speeds associated with any corner. The first is the **approach speed**, which is simply the speed of travel when the corner is first perceived by the rider. It can be any speed consistent with the conditions and the rider's skill and preference. The second is known as the **entry speed**, which is the speed as the rider makes the steering input to begin the lean. We'll deal with this one in detail in a moment. The third is the **exit speed**, which is the speed as the bike leaves the turn and enters the ensuing straight section or another turn.

Of these three speeds, the entry speed is the most critical, because it determines how safely and smoothly the turn can be made.

Approach / Slow

The approach speed is reduced to entry speed prior to the turn. This is the SLOW part of our basic procedure and involves rolling off the throttle, using both brakes, and downshifting as appropriate. The point where this begins and the strength of the brake application is determined by the amount of speed to be lost, the distance available, the braking ability of the machine under existing conditions, and the braking skill of the rider.

Selecting an entry speed is a very complex decision. It depends on the rider's perception of the turn radius, surface condition, and slope; limitations on the line of sight; the speed, position, and direction of other traffic; and the presence of fixed hazards. It also depends on the rider's ability and willingness to use the motorcycle's available cornering performance and, most important from a safety perspective, the ability to respond to the worst-case scenario PREDICTED during the approach.

The need to select a clearly conservative entry speed when the exit is not visible has already been mentioned. Here the need to be able to respond to our worst-case prediction dominates our decision. When this is not the case, then we are free to choose an entry speed that is consistent with the other factors. We'll get into it in greater detail when we discuss the ROLL part of our recommended procedure, but at this point we should define the **upper limit** on entry speed. It is the speed that will permit a gradual roll on of the throttle from the entry point (or the point where the exit becomes visible) through to the exit. Entry speed may be lower than this, but it should never be higher.

Cornering Sequence

With the establishment of the entry speed, the SLOW portion of the cornering procedure ends. LOOK is next; although, as we pointed out earlier, it is really just a continuation of the SEARCH aspect of our overall riding strategy. However, there are some specific aspects of the LOOK that deserve special attention.

Look

The first is that it should involve not just a movement of the eyes but a turn of the head so as to "face" the exit and the intended path after the turn. For gradual turns, this is a minor turn of the head; for sharp turns, it is an exaggerated head turn; and for U-turns, it means turning the head as far as it will turn. The reasoning behind this technique is that it not only allows the rider to SEARCH more effectively, but it also provides what we call "visual directional control." This means that the mind tends to "automatically" make the control inputs necessary to make the motorcycle go where the rider is looking. It also tends to discourage looking down, which causes balance problems. And it prevents wobbling by permitting the rider to perceive the turn as a single, coordinated maneuver rather than as a series of short arcs.

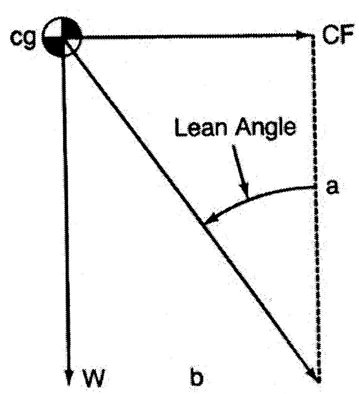
One final aspect of the head turn associated with the LOOK is that the eyes should be kept level with the horizon. The reason for this recommendation is that some individuals tend to become disoriented if their head is tilted while in a turn. Not all people are affected in this way, but keeping the eyes level is a good idea. Those who are prone to this reaction will be spared the problem, and it doesn't hurt anything for those who don't have the problem.

Lean

This brings us to the LEAN in our procedure. There are two ideas to get across here: (1) the motorcycle must lean to turn and (2) lean angle is most quickly, effectively, and precisely controlled through the use of pressures on the handgrips. For detail on the second topic look at the supplement on "Countersteering." For now, let's look at why leaning is required.

A motorcycle needs to lean to turn for two reasons: First, by leaning, the tires produce much of the cornering force necessary is to make the bike turn. But the principal reason why a motorcycle needs to lean in a turn is to maintain balance. When a motorcycle turns, centrifugal force, acting through the center of gravity (cg), tries to cause the motorcycle to lean toward the outside of the turn. To maintain balance, the cg must be moved toward the inside of the turn (that is, the motorcycle must be leaned) so that the weight, which also acts through the cg, can counteract the centrifugal force by trying to cause the motorcycle to lean farther into the turn. What we have is really a "balance" between two opposing torques, like in arm wrestling. **Diagram 1** illustrates this situation.

Diagram 1: Basic Balance Condition



This diagram is similar to one we saw in the "Traction" supplement. Here, think of the bike as being like one leaf of a door hinge. The axis of the hinge is the line between the contact patches on the ground. The diagram shows that the centrifugal force (CF) acting with the lever arm "a" (the height of the cg above the ground) generates a torque about the axis that tends to lean the bike to the right. The weight (W) acting with lever arm "b" (the lateral or sideways displacement of the cg) generates a torque about the same axis that tends to lean the bike to the left. The magnitude of these torques is simply the product or the force (CF or W) multiplied times its respective lever arm (a or b). When these two torques are equal (CF x a = W x b), the bike is balanced and the lean angle remains constant. If the two torques are not equal, then the lean angle will change in the direction of the stronger torque.

Notice that if the bike is vertical, the weight has no lever arm and can produce no torque to affect the lean. On the other hand, at zero lean angle, the centrifugal force has its maximum lever arm and, therefore, the maximum potential for affecting lean angle. *This is the principal reason why steering input is the most effective way of initiating a lean.* It is also why attempting to use weight shift for this purpose is so ineffective. The rider's weight is too small relative to that of the motorcycle to produce a lateral cg shift big enough to result in a significant lever arm for the weight.

However, as the lean angle increases from zero, the lever arm for the weight gets larger, and the lever arm for the centrifugal force gets smaller.

This means that the effectiveness of the weight in producing an effect on lean angle increases, while the effectiveness of the centrifugal force decreases. Therefore, as lean angle increases, weight shifts become relatively more important, and they can be used to good advantage to make fine adjustments to lean angle while in a turn. Consider, for example "dropping" the inside knee off the tank to initiate a slight increase in lean angle. Some riders use this and similar techniques, and they should not be discouraged from using them. Two ideas that should be discouraged are (1) shifting body weight is the best way to initiate a turn and (2) counter steering is for obstacle avoidance only.

Roll

This leads us to the final step in the recommended cornering procedure, ROLL on the throttle. This part of the technique is based on the need to stabilize the machine on its suspension and to prevent any sudden changes in the distribution of traction between the two tires.

Recall from the supplement on "Traction" that the accelerations that produce changes in speed result in a shift in the relative loading of the tires. They also result in extension or compression of the suspension components. What do these things mean to the rider when the motorcycle is in a turn?

In the "Traction Pie" supplement, we noted that in a corner a significant portion of the available traction is being used for the side forces necessary to make the bike turn, plus the steering forces and driving forces necessary to maintain speed and control. Any excess traction is the reserve for making changes or responding to surprises. We also know that the total cornering force is divided between the two tires based on the relative speed of the wheels.

For large-radius turns, the two wheels are tracking along nearly equal arcs, so each is subjected to approximately the same demand for cornering force. In tight turns, the front wheel is tracking an arc of significantly greater radius than the rear wheel. Therefore, it is traveling faster and has a greater demand for traction.

The distribution of available traction between the tires is determined by the cg location, the angle of incline (if any), the speed (aerodynamic forces), and any accelerations and/or torque-reaction forces that occur from moment to moment. So long as nothing changes abruptly, the traction distribution remains fairly stable. But if the rider introduces changes through the abrupt use of the throttle, there is a rapid shift in available traction from one tire to the other. This could be enough to leave one tire without enough traction to handle its need.

Traction Shifts — Abrupt Deceleration

Suppose, for example, that the throttle is abruptly rolled completely off when the bike is at a large lean angle (or even a small lean angle on an off-camber surface). The deceleration would cause a shift in available traction away from the rear. If the engine braking were strong enough, this could be enough to produce a skid of the rear tire. If not, there still could be a problem at the front.

While the deceleration would make more traction available at the front, it would also have a component (because of the lean angle) that would add to the demand for side force. Therefore, it is possible under certain conditions to produce a skid of the front tire by rolling off the throttle in the turn.

Traction Shifts — Abrupt Acceleration

Similar problems at the rear could be the result of rolling the throttle on abruptly or excessively. The traction available at the rear would go up as a result of the acceleration, but the increased demand for traction—due to high Driving Force and increased Cornering Force as the speed builds—could exceed what is available.

Abrupt Speed Change — Other Difficulties

Other difficulties arise from abrupt increases or decreases in speed in a turn. As such changes occur, the suspension extends or retracts. This will change the ground clearance and steering geometry and can introduce oscillations in the suspension. Reduced ground clearance limits lean angle and can result in loss of traction if parts of the motorcycle start to drag. The steering and suspension changes can result in directional stability and control problems.

Solution to Roll

The solution to all of these problems is to avoid abrupt speed changes in a turn. And since greater ground clearance and extension of the front suspension tend to add to overall stability and control, a gradual ROLL on of the throttle to produce a steady speed or a gentle acceleration is preferable to a deceleration. But we should emphasize that what is called for is a gentle, gradual roll-on only; too much acceleration or speed can drive the demand for traction beyond what is available, and a skid would occur.

Supplement #4
Leaning Out and Leaning In

Leaning Out

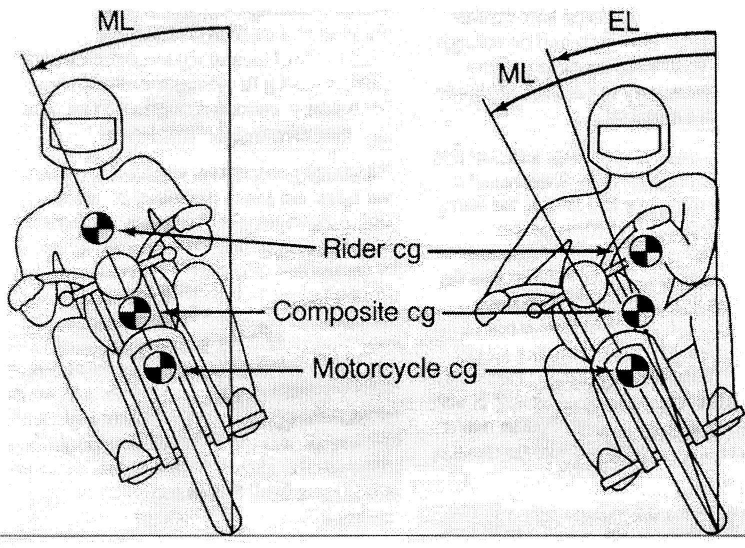
Since increasing the motorcycle's lean angle is a way of ensuring the tightest possible turn within steering and traction limits, it would be nice if there was a way of increasing the motorcycle lean angle without having to increase steering angle or speed. Fortunately, there is a way to do this. It is called counterbalancing, or "leaning out."

To see why this works, we must first realize that, as we have just seen, the effect of reducing turning radius by increasing lean at a given steering angle is a matter of geometry only. That is, the turn radius is dependent only on the steering angle and the amount of lean of the motorcycle's wheels. On the other hand, we recall from the "Cornering" supplement that the balance condition is determined by the struggle between weight and centrifugal force, each acting through the overall or composite cg of the rider-motorcycle combination. Therefore, it is the effective lean angle (the angle between the plane containing the composite cg and the vertical) that is important in determining balance.

When the rider leans with the motorcycle, the motorcycle lean angle and the effective lean angle are the same. "Leaning out" shifts the composite cg slightly to the outside, and the effective lean angle is reduced relative to the motorcycle lean angle. This is shown in **Diagram 2,** where ML stands for motorcycle lean, which is measured from vertical to the motorcycle centerline, and EL stands for effective lean, which is measured from vertical to the line through the composite cg.

What does this do for us? Since the effective lean angle is smaller, the weight has a shorter lever arm; so the need for centrifugal force to maintain balance is reduced. This means that the large lean angle necessary for a small turn radius can be maintained at a lower speed than if the rider were to lean with the motorcycle. There are two potential reasons for leaning out: (1) it permits cornering at a slightly lower speed in situations where traction might be lower than normal; and (2) the rider is not comfortable with either the speed required to maintain balance or with the perception of the lean angle required to make the turn while leaning with the machine.

Diagram 2: The Effect of Leaning Out



Note that the effectiveness of "leaning out" depends on how much the rider's weight is able to produce a significant shift in the composite cg. This is determined principally by the ratio between the rider's weight and the weight of the machine. A heavy rider on a light machine can produce a relatively large cg shift. A light rider on a heavy machine can't shift the composite cg very much. One conclusion from this is that on any given machine, the heavier rider has the potential to turn at a slower speed than the lighter rider. Nonetheless, every rider can gain some benefit from "leaning out" in a tight turn.

Highway-Speed Turns

The next topic is at the opposite end of the turn spectrum, turns at highway speeds. The most typical problem that arises with such turns is when the rider misjudges the radius and/or the slope of the turn and discovers, while in the turn, that the radius must be tightened. So long as the rider stays within available traction, stability, and control limits, then the principal concern is one of having enough ground clearance to increase lean angle.

At highway speeds, the centrifugal force can compress the suspension and reduce ground clearance significantly, so the option of increasing lean angle may be severely limited. What else can the rider do to decrease turn radius?

One option is to reduce speed. But as we have seen in the supplement on "Cornering," this can result in stability and control problems if not done carefully, and it can further aggravate the ground-clearance problem. Fortunately, so long as there is a traction reserve, there is another option.

As we have already covered, the turn radius is determined by the lean angle and the steering angle. So when ground clearance limits the motorcycle lean angle, the rider can turn sharper only by increasing steering angle. But if the rider increases the steering angle to reduce the turn radius, the centrifugal force increases accordingly. The problem then becomes how to keep this increased centrifugal force from acting to decrease the lean angle and increase the turn radius. "Leaning in" is a technique that can help in this situation.

Leaning In

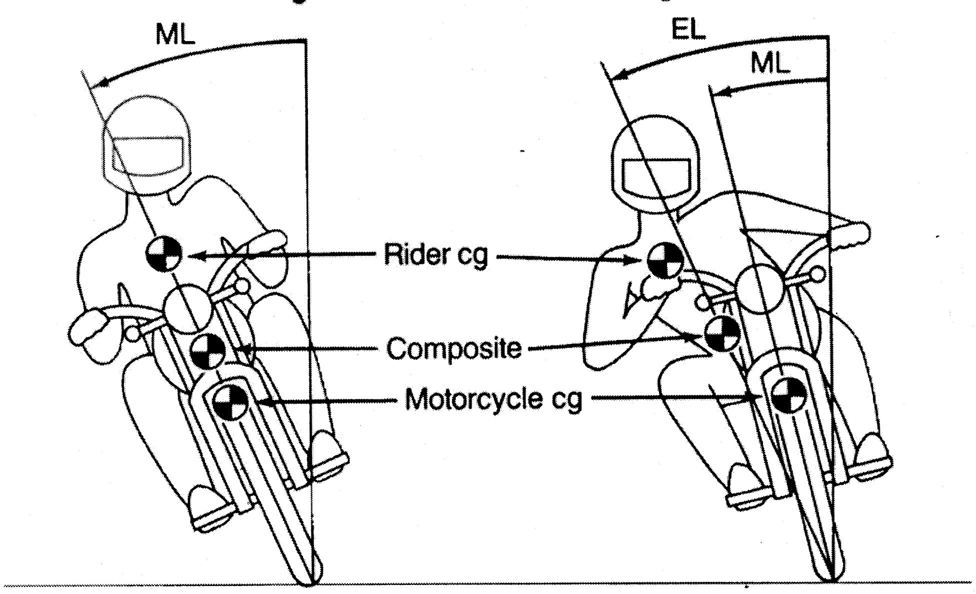
Recall from the discussion on tight turns that the rider can shift the composite cg away from the centerline of the motorcycle by shifting weight to the side. This produces an effective lean angle that is different from the motorcycle lean angle. In this case the rider needs to increase the effectiveness of the weight to counteract more centrifugal force, so the effective lean angle must be greater than the motorcycle lean angle. This is achieved by "leaning in," by concentrating weight on the inside of the turn. This is shown in **Diagram 3**. Again, ML stands for motorcycle lean angle, which is measured from vertical to the centerline of the machine. And EL stands for effective lean angle, which is measured from vertical to the line through the composite cg. As with "leaning out," the effectiveness of "leaning in" depends on the weight of the rider relative to that of the machine. On a given machine, the heavier the rider, the greater the potential for benefit from the technique.

Summary

In summary, "leaning out" results in an effective lean angle that is less than the motorcycle lean angle and permits cornering at lower speeds at any given turn radius and steering angle. It is useful when making tight turns at low speeds when steering angle can't be increased or when speed must be minimized because traction is marginal. "Leaning in" results in an effective lean angle that is greater than the motorcycle lean angle. Provided that the steering angle can be increased, it permits sharper turns at any given speed when ground clearance limits motorcycle lean angle. It is useful in highway-speed turns and in decreasing-radius turns, provided that ground clearance, rather than traction, is the dominant problem.

It is important to understand that neither "leaning out" nor "leaning in" has any direct effect on the amount of traction available, because they affect neither the tire loading nor the coefficient of friction. Therefore, neither technique is some sort of "magic" that will allow the machine to corner at a speed greater than that limited by traction. These techniques are principally useful in overcoming limitations in steering angle, ground clearance, and/or rider comfort. They can also affect stability and control to some extent, because they tend to lower the composite cg, in addition to shifting it laterally. But such effects are generally quite small and usually not significant.

Diagram 3: The Effect of Leaning In



Cornering Supplement # 5

Cornering

The Long and Winding Road

Cornering is one of the things that makes motorcycling so enjoyable. The challenge of setting up the perfect line and properly executing cornering technique is almost like ballet in its precision and grace. Many riders search for the "perfect" road, but any twisty passage can be more enjoyable through knowledge and skill. The basic cornering technique is similar for all types of roads, motorcycles, and riders. Slow, Look, Lean, and Roll . . . that's all there is to it! Of course, every situation is different, and this simple four-step process doesn't tell the whole story. That's where the challenge comes in: knowing the how, where, and why of Slow, Look, Lean, and Roll when riding through turns.

The mental activity of riding using a management strategy such as SIPDE has already been discussed a few times. Our cornering procedure is one example of applying this basic strategy to a specific riding situation. No corner exists all by itself; it is part of a ride that extends in both directions. You have to aggressively Scan, Identify, Predict, Decide, and Execute up to the corner, through it, and beyond. Let's begin with the approach to the turn and set the scene for our cornering procedure.

What You See Is What You Get

When you first see a turn in your path of travel, you face two decisions. The road is quite a bit wider than you or your motorcycle. In order to be prepared to negotiate the curve, you have to choose a path through it (or your "line") and an appropriate speed. Both of these decisions require judgment, based on your knowledge and the facts you have about the curve ahead. There is not a lot of time to assess the situation as you ride, so take the time now to examine some of the things you will need to consider.

First, you have to decide what sort of corner it is. It might be a sharp corner or a wide "sweeper." Does it stand alone, or is it a part of a series of turns? What about the radius—does the turn get tighter or widen? Remember the effect of road camber on traction and lean angle? Surface defects or hazards will surely affect your path, like conflicting traffic or potholes. Can you see completely through the corner? If your line of sight is restricted, you might have to make assumptions about several of these things.

That's a lot to find out in a short period of time. A mistake evaluating any of these facts could mean trouble. Sight is your most effective tool for gathering information. The earlier you detect a problem, the more time you have to react. It is pretty clear that it helps to see as much of the corner as possible. Remember the concept of maintaining an aggressive search with a 12-second visual lead? That applies to more than just urban situations. It may not be possible to always maintain a 12-second line of sight, but the inability to scan far enough ahead should put you on alert. You must consciously work to maximize your line of sight.

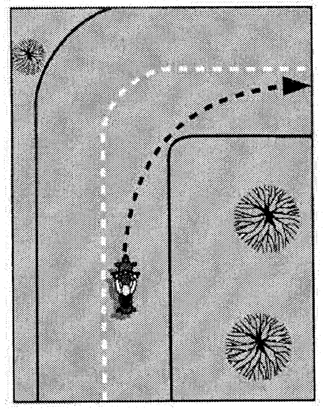


Diagram 14-1: Simple, constant-radius turn

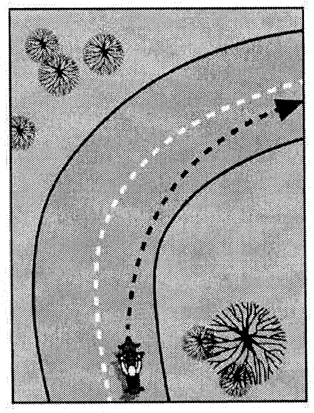


Diagram 14-2: Increasing-radius turn

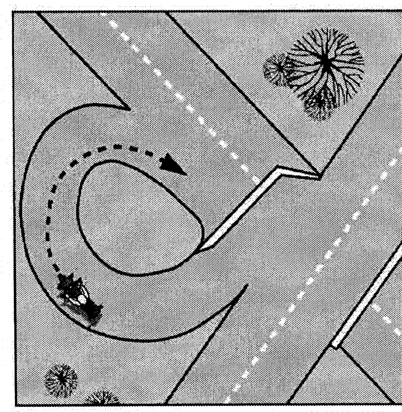


Diagram 14-3: Decreasing-radius turn

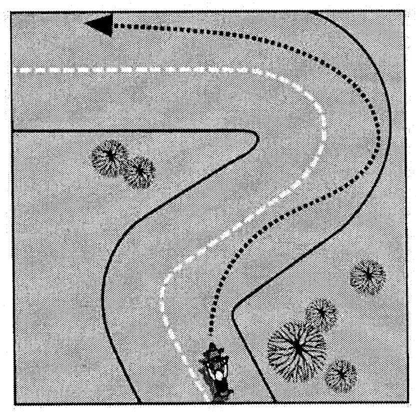


Diagram 14-4: Multiple turns

The decreasing-radius turn is the most challenging of these three types. If you are approaching a blind turn, it would be best to assume the worst: the portion of the turn that you cannot see has a decreasing radius. If you set up for a late/delayed apex, only to discover that the turn has a constant or increasing radius as the exit comes into view, this is a pleasant surprise. The late/delayed apex almost always results in greater reserves and more options for you to adjust to the unexpected. In that sense, it is potentially the safest option for any turn.

Apex—Multiple Turns

We have been discussing apex selection for a variety of single turns. There is still a fine line between each apex when one good turn leads to another, but it's not always the simplest one. The rules that we have covered for individual turns don't always give you the best line through the series of corners. Consider a sequence of two turns where the first is a constant radius and the second is a decreasing radius in the opposite direction. If you select a normal or center apex for the constant-radius section, you wind up on the wrong side of your lane to enter the decreasing-radius part. By delaying your apex for the constant-radius section, you will be in a better place to enter a path with a late/delayed apex for the decreasing-radius turn. This example illustrates why it is so important to Scan well ahead and Identify or Predict what is going to happen next before Deciding on a path and an apex for any turn.

In general, a delayed apex (as in Diagram 14-4) will maximize your line of sight until the exit or next turn becomes visible. Your choice of line after the apex permits you to maximize the effective turn radius through the exit of the turn. In many cases, the "ideal" path and apex aren't available because roadway and/or traffic conditions interfere. Once again, the use of a strategy like SIPDE is valuable in finding the best compromise.

Add Two Teaspoons Throttle . . .

Your speed changes as you slow for a corner and again as you roll on the throttle through the curve. We can describe these speed changes by focusing on three distinct points in the curve. The speed that you happen to be traveling when you first see the corner is your **approach speed.** Approach speed is determined by the environment and your ability to slow to an appropriate **entry speed,** which is the speed you are traveling when you begin the lean. We will call your speed at the exit of the turn, naturally enough, your **exit speed.** Of these three speeds, the entry speed is the most critical, because it determines how safely and smoothly the turn can be made.

Approach/Slow

The first part of the turning technique is to reduce your approach speed to a proper entry speed *prior* to the turn. This is the Slow part of the basic procedure. You already know the mechanics of this process: it involves rolling off the throttle, using both brakes, and downshifting as appropriate. The point where you should begin slowing, and the amount of braking, is determined by the amount of speed to be lost, the distance available, the braking ability of the machine under existing conditions, and your braking skill.

Selecting an appropriate entry speed can be a complex decision. Your perception of the turn radius, surface condition, and slope will come into play. You have to consider limitations on your line of sight and path of travel. These will be affected by the speed, position, and direction of other traffic and the presence of fixed hazards. Your entry speed will depend on how much of the motorcycle's available cornering performance you decide to use. Most importantly, it should allow you to respond to the worst-case scenario Predicted (the "P" in SIPDE) during the approach.

Your entry speed for a blind turn will be limited by any number of possibilities. Even if you know that the turn's radius does not decrease, something could be blocking your path of travel. Your decision is dominated by your worst-case prediction(s). Once you can see the exit, you will be able to judge all of the other factors more accurately. The information you gather works together with your experience, skill, and knowledge to define an *upper limit* on your entry speed. It is the speed that will permit a gradual roll on of the throttle from the entry point (or the point where the exit becomes visible) through to the exit. Entry speed may be lower than this, but it should never be higher.

The Slow portion of the cornering procedure ends once your entry speed is established. You are still traveling in a straight line and you have just arrived at the curve's entry point. The next step is to Look. We pointed out earlier that Look is related to the Scanning that is part of your overall riding strategy, but there is more to it.

Look

When you Look through a curve, you *turn your head* to face the exit and the intended path after the turn. Your eyes continue to move about and scan the riding environment, but the center of your field of vision is where you will be going. This is a minor turn of the head for gradual turns. You may need to exaggerate the head turn for sharp turns to face the exit. For U-turns, it means turning your head *as far as it will go.*

This technique not only allows you to Scan more effectively, it provides "visual directional control." Your mind tends to automatically make the control inputs necessary to cause the motorcycle go where you are looking. Have you ever found yourself drifting toward the side of the road while looking at some attractive scenery? That's visual directional control. Facing the turn's exit also tends to discourage looking down, which may cause balance problems. It helps you to perceive the turn as a single coordinated maneuver rather than a series of short arcs and can result in a smoother line.

When you turn your head to Look through a curve, it helps to keep your eyes level with the horizon. Some people tend to become disoriented if their head is tilted while in a turn. Keeping your eyes level helps you to better judge distances, maintain a sense of balance, and avoids possible orientation problems.

Lean

As you Look through the turn, you need to Lean the motorcycle. We know from the previous chapter that your motorcycle must lean to turn and that lean angle is most quickly, effectively, and precisely controlled through handlebar pressure. This begins a series of events, as illustrated in the previous chapter (see page 128).

A motorcycle needs to lean in a turn for two reasons. First, the lean of your tires produces much of the cornering force necessary to make the bike turn. The other reason that you have to lean in a turn is to maintain balance. When a motorcycle turns, centrifugal force acts through the center of gravity (cg) to try to lean the motorcycle toward the outside of the turn. To maintain balance, the motorcycle must be leaned into the turn so the weight can counteract the centrifugal force. We end up with a "balance" between two opposing torques, like in arm wrestling.

When you are perfectly vertical on your bike and not moving, weight has no lever arm to tip it to the side and it will be balanced when you pick up your feet. If anything moves even slightly, the weight will then have a lever arm to act, and you fall to the side unless you put your feet back down.

Let's put the bike in motion in a steady turn. Diagram 14-5 shows that the centrifugal force *(CF)* acting with lever arm *a* (the height of the cg above the ground) generates a torque to the right that tries to straighten you up. The weight *(W)* acting with lever arm *b* (the sideways displacement of the cg) generates a torque that tries to lean you more to the left. These torques are simply the product of the force *(CF or W)* multiplied by its respective lever arm *(a or b)*. When they are equal *(CF x a = W x b)*, you are balanced and the lean angle remains constant. If the two torques are not equal, then your lean angle will change until balance is restored.

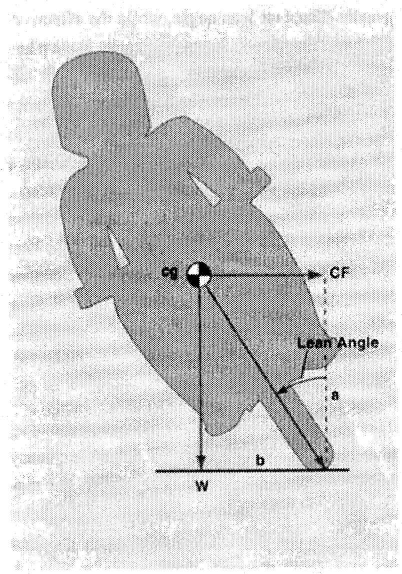


Diagram 14-5: Basic balance condition

When you are vertical and moving in a straight line, the weight has no lever arm to affect the lean, just like when you were stopped. Centrifugal force has its maximum lever arm at zero lean angle, and its maximum potential for affecting lean angle. Any change of direction, even slight, will involve tire side forces that create a sideways force (centrifugal force), which acts through its maximum lever arm to lean the motorcycle in the direction of the turn. *This is the principal reason why steering input is your most effective way of initiating a lean.* It is also why shifting your weight is relatively ineffective for that purpose. Since your weight is only a small fraction of the moving motorcycle, you cannot produce a sideways cg shift big enough to create a significant lever arm for the weight.

The lever arm for weight gets larger as your lean increases, and the lever arm for centrifugal force gets smaller. This means that weight has a greater effect on lean angle, while the effectiveness of centrifugal force decreases somewhat. Weight shifts can therefore be used to your advantage for making fine adjustments once you've initiated a turn. One example involves "dropping" the inside knee off the tank for a slight increase in lean angle while in a turn.

The most important idea that we can express regarding lean is that countersteering is the best way to initiate *any* turn and that shifting your body weight is a poor substitute. Countersteering is an essential part of everyday riding technique—it's not just for obstacle avoidance.

Roll

This leads us to the final step of the cornering procedure, **Roll** on the throttle. There are many benefits of a gradual roll. It stabilizes the machine on its suspension and prevents sudden changes in the distribution of traction between the two tires. Ground clearance is improved, while the centrifugal forces associated with balance are not disrupted.

We examined how accelerations that produce changes in speed result in a shift in the relative loading of the tires in the traction chapter. They also extend or compress your suspension as the motorcycle's weight is transferred. Both of these effects have an impact on your ability to smoothly negotiate a curve.

Cornering can use a significant portion of your available traction. Side forces that make the bike turn are combined with the steering and driving forces necessary to maintain speed and control. Any excess traction is your reserve for making changes or responding to surprises.

We also know that the cornering force required depends greatly on speed. For large-radius turns, both of your wheels are tracking along nearly equal arcs and traveling at approximately equal speeds. In tight turns, the front wheel tracks an arc of somewhat greater radius than the rear wheel. This means that your front tire is traveling faster and its demand for traction may be greater than the rear.

We have already discussed the factors that determine the distribution of available traction between the tires in some detail. In a curve, the traction distribution remains fairly constant as long as nothing changes abruptly. Sudden shifts in tire loading or power would result in a rapid shift in available traction from one tire to the other. This could leave one tire without enough traction to meet the demands of its users.

Traction Shifts—Abrupt Deceleration

Suppose that you abruptly roll off the throttle completely when the bike is at a large lean angle. The deceleration would cause a shift in available traction away from the rear. This might be enough to produce a skid of the rear tire if the engine braking were strong enough.

Deceleration would make more traction available at the front because of the weight transfer. This same transfer of weight will have a relative sideways component that adds to the demand for side force because the motorcycle is leaning. With more traction available *and* more being used, the balance of supply and demand may still produce a skid of the front tire if you roll off the throttle while turning.

Large lean angles aren't the only situation where abruptly closing the throttle might be a problem. The same kind of difficulties may arise at a small lean angle on an off-camber surface, for example.

Traction Shifts—Abrupt Acceleration

Rolling the throttle on abruptly or excessively may produce some more traction on the rear tire due to weight transfer, but the increased demands of driving and side force can quickly eat up any additional reserve. For very abrupt inputs, the rear tire would likely begin to slide out from under the motorcycle before any significant weight transfer could take place.

Abrupt Speed Change—Other Difficulties

Other difficulties can arise from abrupt increases or decreases of power in a turn. The suspension extends or retracts in response to changes in speed, which affects the ground clearance and steering geometry of your motorcycle. This can introduce oscillations in the suspension, which reduce its effectiveness or cause instability. Reduced ground clearance limits your lean angle and in extreme cases can result in loss of traction if parts of your motorcycle start to drag. Steering and suspension changes combine with lessened ground clearance and limited traction reserve to reduce directional stability and produce possible control problems.

Rolling Home

The solution to all of these problems is to avoid abrupt speed changes in a turn. Since greater ground clearance and extension of the front suspension tend to add to overall stability and control, deceleration can be avoided by gradually rolling on the throttle to produce a steady speed or a gentle acceleration. A gradual roll-on prevents too much acceleration or speed from driving the demand for traction beyond the limit and causing a skid.

The rewards of practiced and proper cornering technique are a greater traction reserve and a better feeling of stability and control. These are some of the goals that help make motorcycling safer and more enjoyable.

Self-Test for Chapter 14: Cornering

Choose the best answer to each question.

1. What are the two things you must choose when preparing to negotiate a corner?

   ____

   ____

2. What is the apex of a corner?
   a. Widest point of the turn.
   b. Point closest to the inside.
   c. Midpoint of the corner.
   d. Highest point of the curve.

3. A late or delayed apex is best used for what type of turn?
   a. Constant radius.
   b. Increasing radius.
   c. Decreasing radius.
   d. Off-camber turns.

4. The speed at which you enter a corner is the most critical. True or false?

5. Why is it important to turn your head to look when cornering?
   a. So that you will face the turn's exit and your intended path of travel.
   b. So you can spot potential danger in the adjoining lane.
   c. To maintain balance through the turn.
   d. To see if anyone is following you through the corner.

(Answers appear on page 176.

Cornering Supplement #6

Low- and High-Speed Turning

15

You Put Your Right Knee In

We have already pointed out that shifting your weight is not a very effective way to initiate a lean for turning and balance. Keeping your knees against the tank and leaning with the motorcycle in turns prevents the center of gravity from shifting and generally gives you better control and stability.

There are some cornering situations, however, where shifting your weight off-center can be used to your advantage. We will be covering some of these special riding techniques and how they apply to low-speed tight turns, turns at highway speeds, and decreasing-radius turns.

Slow, Tight Turns

Tight turns are intimidating to some riders because they require relatively large lean angles at low speeds. Leaning out or counterbalancing can make tight turns easier and more controllable. To fully understand what "leaning out" does, let's first consider why large lean angles are necessary to make tight turns.

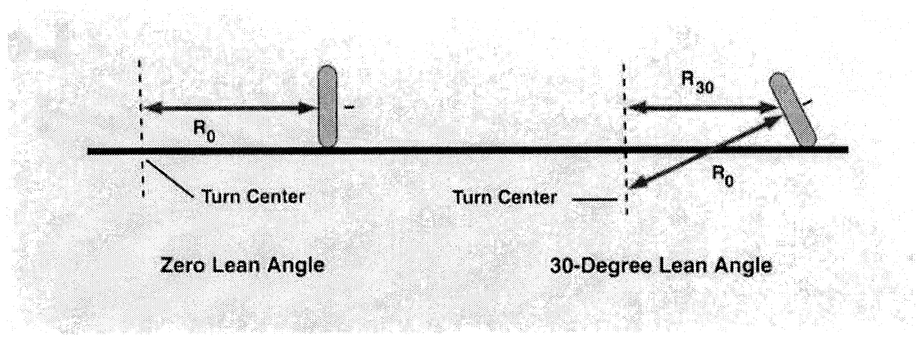
If you were to stand next to your motorcycle, turn the handlebars full-lock to the left, and walk it without leaning, your motorcycle would follow a circle that is entirely a function of the steering angle. To ride through a turn using this same technique, you would have to go slowly and lean your body inward, keeping the centrifugal force low. It should be possible to make a circle of about the same size as when you walked the motorcycle depending on your skill and the steering angle you can manage. Once that point is reached, the only way to decrease the turn radius further is to lean the motorcycle.

To illustrate why leaning the motorcycle causes the turn to tighten, take a look at Diagram 15-1. On the left, you see a view of a motorcycle rear tire. The front tire is not shown to keep the diagram simple. Imagine that the motorcycle is being turned sharply to the left with a nearly zero lean angle and the steering is at or near the stop, just like our previous "walking experiment." The center of the curve and the turn radius ***R_0*** are shown.

On the right is a similar view with a lean angle of about 30 degrees. Imagine the steering angle is still at or near the stop. The distance to the "center" of the curve is the same, but the center is now well below the surface. Neglecting wheelbase effects, you can pretend that the motorcycle is now riding around the base of an upside-down cone. The **effective** turn radius ***R_{30}*** is measured from the point on the surface that is directly above the center of the turn. Looking at Diagram 15-1, we see that ***R_{30}*** is significantly shorter than ***R_0***, which means that the turning radius when leaning at a 30-degree angle is tighter. As the lean angle increases, the "cone" gets sharper, and the effective turn radius gets smaller.

Remember what happens to the relationship between weight and centrifugal force in a steady turn? To maintain balance, these two opposing forces must offset each other. With large lean angles, the weight has a greater lever arm and cen-

Diagram 15-1: The effect of lean on turn radius



trifugal force has a smaller lever arm. This means that more centrifugal force is necessary to balance if lean angle were to increase.

Some of the required centrifugal force results from the tighter turn, but this may not be enough to balance the increased effect of the weight. If you could steer more into the turn and make it even tighter, that could produce the centrifugal force necessary for balance. If you are unable to steer more in a very tight turn, you must increase speed to maintain balance. In other words, you have to add power to turn tighter. As strange as this might seem, it is required to maintain your balance in this situation.

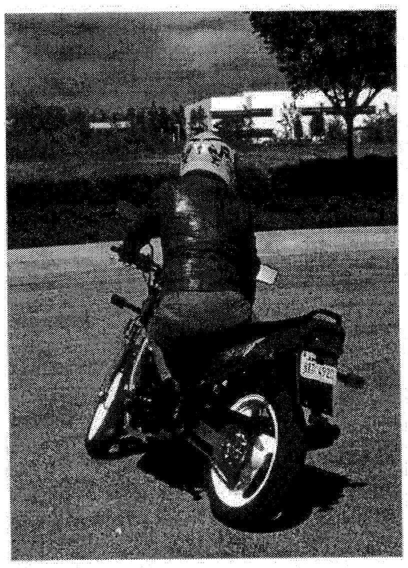
Perhaps you have had the experience of using a small amount of power to recover balance in a low-speed, tight turn instead of touching your foot to the ground. This works well because it takes only a small increase in speed to produce useful change in centrifugal force. You should use the throttle smoothly and gently since it is easy to get too much centrifugal force if the engine's throttle response is rapid. Using a higher gear, slipping the clutch, or using some rear-brake pressure to limit your power to the rear wheel can result in smoother overall control.

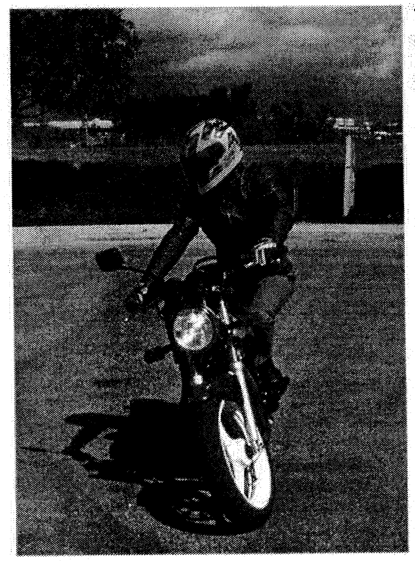
There are limits to how far you can lean the motorcycle and how much speed you can use to maintain balance. Your lean angle is limited by the ground clearance. The effect of centrifugal force (or speed) is limited by the amount of traction available and your ability to control acceleration precisely at low speed. In a low-speed, tight turn, the front tire is tracking a much wider arc than the rear. This means that the front is going faster and will likely run out of traction first if too much speed is used.

Leaning Out

Once you are at the maximum steering angle and your speed is near the limits of traction, it would seem that you couldn't tighten up a turn any further. Leaning farther would require more speed to balance the weight, unless there was some way to lean the motorcycle farther *without* leaning any more weight. This would require a weight shift in the opposite direction of the lean. One way to accomplish this is by rider counterbalancing, or "leaning out."

Reducing your turning radius by increasing lean angle is a simple matter of geometry. The turn radius is dependent mainly on the steering angle and the amount of lean of the motorcycle's wheels. On the other hand, the balance condition is determined by the relation between weight and centrifugal force acting through the center of gravity of the rider-motorcycle combination. We can call the "lean" of the center of gravity the "effective" lean angle. If we can move the overall center of gravity away from the center of the motorcycle, we can affect balance (and speed) without changing the turn radius. This also means that you can balance at a greater motorcycle lean angle as long as you don't increase the effective lean angle any more.





Two views of a motorcyclist leaning out to tighten up a turn.

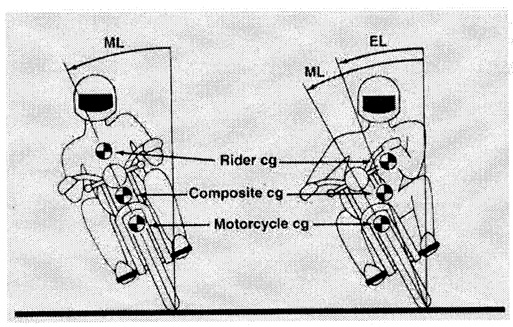


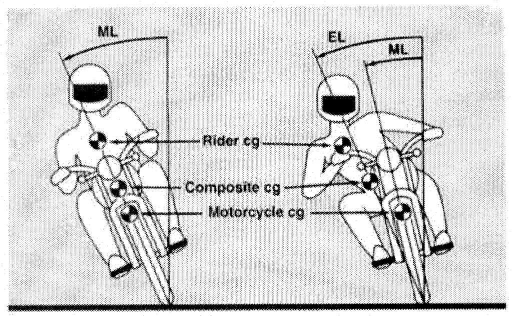
Diagram 15-2: The effect of leaning out

The motorcycle lean angle and the effective lean angle are the same when you lean with the motorcycle. "Leaning out" shifts your weight (and therefore the composite center of gravity) slightly to the outside. This makes the effective lean angle less than the motorcycle lean angle as shown in Diagram 15-2. ***ML*** stands for motorcycle lean, which is measured from vertical to the motorcycle centerline, and ***EL*** stands for effective lean, which is measured from vertical to the line through the composite center of gravity.

With a smaller effective lean angle, the need for centrifugal force to maintain balance is reduced. This means that the large lean angle necessary for a small turn radius can be maintained at a lower speed than if you were to lean with the motorcycle. Your maximum lean angle is still limited by any parts that might drag. Leaning out permits cornering at a slightly lower speed in situations where traction might be lower than normal. Lower speeds also allow you to maintain a greater traction reserve. The actual amount of lean will "feel" like it is less because you are more vertical than the motorcycle.

The effectiveness of "leaning out" depends on how much you can shift the composite cg. A heavy rider on a light machine can produce a relatively large cg shift, while a light rider on a heavy machine may not be able to shift the composite cg very much at all. Other factors being equal, this means that on any given machine, heavier riders have the potential to turn more tightly at slower speeds than lighter riders. With the proper technique, every rider can benefit

Diagram 15-3: The effect of leaning in



from knowing how to counterbalance in slow, tight turns.

Highway-Speed Turns

Balance is not a problem when turning at highway speeds. Plenty of centrifugal force is available for balance at high speed. The greater force requires more traction, and we have already covered traction management in previous chapters. Another concern is having enough ground clearance for the lean angles required. Centrifugal force can compress the suspension and reduce ground clearance at highway speeds. What can you do if you have to tighten your turn radius when there isn't enough ground clearance to lean more?

The simplest answer is to gradually reduce speed. Rolling off the throttle or braking abruptly may result in the stability and control problems that we discussed in the last chapter. It may also aggravate your ground-clearance problems if the suspension compresses even further. If you need to tighten your turning radius quickly when you are already leaned well over and your ground clearance is limited, deceleration is not a very attractive option. Fortunately, you have another choice, *if* you have managed your traction effectively and have enough reserve.

When we discussed slow, tight turns, we showed that turn radius is determined mainly by your lean and steering angles. You normally increase your steady-turn steering angle indirectly by countersteering. The motorcycle leans more (or less) and the front-end geometry helps do the rest. Effective steering angle increases *as a result* of greater lean to "track" the reduced turn radius.

If the lean angle cannot be increased any more, the problem becomes how to increase the steering angle and reduce the radius. We would then have to prevent the resulting centrifugal force from decreasing the lean angle and increasing the turn radius. "Leaning in" is a technique that can help in this situation.

Leaning In

We already saw how, in tight turns, you can shift the composite cg away from the centerline of the motorcycle by shifting weight to the outside. This produces an effective lean angle that is less than the motorcycle's lean angle and reduces the demand for centrifugal force. If you run out of ground clearance while you still have adequate traction in higher-speed turns, the challenge becomes how to counteract *more* centrifugal force. If you can't slow down, your effective lean angle must be *greater* than the motorcycle's lean angle.

You can accomplish this by "leaning in," or concentrating more weight on the inside of the turn as shown in Diagram 15-3. Again, ***ML*** stands for motorcycle lean angle, which is measured from vertical to the centerline of the machine. ***EL*** stands for effective lean angle, which is measured from vertical to the line through the composite cg.

Leaning in can help if you unintentionally enter a turn too fast. If you enter a turn slightly overspeed and you have sufficient traction reserve, you might choose to keep the throttle on to maintain ground clearance and suspension stability; then press to lean more and shift your weight to the inside. The actual technique may be as simple as hanging out a knee on the inside of a turn, or you might shift your weight on the seat.

If you are riding much too fast, one technique is to countersteer to straighten the bike and brake hard in a straight line to reduce your speed, then quickly countersteer to re-enter a tighter radius at a lower speed. These methods are not recommended for routine riding. They simply give you an option if you have misjudged the appropriate entry speed for a turn. Your technique has to be precise to successfully execute this maneuver. It is especially important to look far through the curve to maintain visual directional control.

You may have seen racers hanging out a knee at the track. They use this effect to push the limits of traction and ride faster through turns. On the street, you have to maintain a reserve to deal with less predictable conditions, as we have already discussed. When you use the technique of "hanging off" to decrease the radius of a turn, you must remember that more traction is needed. Leaning in doesn't create additional traction, it simply permits you to use more of the available reserve.

As with "leaning out," the effectiveness of "leaning in" depends on the weight of the rider relative to that of the machine. Heavier riders can produce more of an overall weight shift than lighter riders, but any rider using this technique can produce more ground clearance when cornering at highway speeds.

Summary

Counterbalancing (or "leaning out") can be useful when making tight turns at low speeds, when steering angle can't be increased, or when speed must be kept low because traction is marginal. "Leaning in" permits sharper turns at any given speed when ground clearance limits motorcycle lean angle. It is useful in highway-speed turns and in decreasing-radius turns as long as there is sufficient traction.

Neither technique has any direct effect on the amount of traction available because they don't change the tire loading or the coefficient of friction. There is no magic that will allow you to corner faster than traction will allow. These leaning techniques are valuable to help deal with the limits of steering angle or ground clearance, and for the rider's comfort.

Self-Test for Chapter 15: Low- And High-Speed Turning

Choose the best answer to each question.

1. How can you make tight turns easier and more controllable?
   a. Slip the clutch.
   b. Tap the brakes.
   c. Lean out or counterbalance.
   d. Put your foot out and use it as a pivot point.
2. Which of the following will tighten your turn radius if you can't lean more?
   a. Gradually reduce speed.
   b. Gradually increase speed.
   c. Brake hard.
   d. It's not possible.
3. When should you "lean in" while cornering?
   a. For all high-speed turns.
   b. While accelerating at the exit.
   c. For slow, tight turns.
   d. When you enter a turn slightly overspeed.
4. "Hanging off," the technique road racers use to decrease the radius of a curve, creates more traction. True or false?

(Answers appear on page 176.)